

Semi-Annual Status Report - NASA Research Grant (NsG-327) - April 1, 1969  
NGR 24-003-007

STUDIES OF THE EFFECTS OF GRAVITATIONAL AND INERTIAL FORCES ON CARDIOVASCULAR  
AND RESPIRATORY DYNAMICS

The major portion of this report consists of the appended description of a computer-controlled scintiscanning assembly and associated digital computer data processing technics developed during the last year for study of the effects of changes in the gravitational-inertial force environment on the regional distribution of blood flow in chimpanzees.

In addition, the fabrication of the biplane videometry system has been completed and initial check-out tests have been carried out during the last month, of the complete assembly, including the computer interface system, using a prototype model video disc recorder which was not received in Rochester until March 17, 1969. Delivery of the final model video disc assembly especially adapted for the project by Data Memory Incorporated, has been delayed until May 15, 1969.

Descriptions of the system used for biplane roentgen videometry have been published (1) and included in the semi-annual report dated October 1, 1968, submitted under this grant. Descriptions of the operator-interactive video signal gating and processing system and the video quantizer cardiac border recognition system have been published (2) and included in the April 1 and October 1, 1968 progress reports submitted under this grant.

Figure 1 is a block diagram, which shows how these components of the assembly are incorporated into the complete biplane roentgen videometry, on-line digital computer system for sixty per second measurements of the shape and volume of the left ventricle.

Figure 2 shows the timing sequence of the video signal control pulses, and their relationship to the control logic command pulses which control the measurements of the dimensions of the biplane projections of the left ventricular silhouette, and the transfer of these values to the computer at the termination of each of the 50-60 horizontal video lines which comprise the sixty per second biplane images of the left ventricle.

CASE FILE  
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Figure 3 shows pictures of on-line computer generated three-dimensional cathode-ray tube displays of the shape of the left ventricle at end-diastole and end-systole, obtained from biplane videoangiograms recorded initially on videotape. The computer programs for generating these displays have been worked out in this laboratory by Mr. James Greenleaf and Dr. Craig Coulam.

Studies of the effects of plus and minus  $G_y$  (i.e., right and left lateral acceleration) in the range from 1 to 6G, on the regional distribution of pulmonary blood flow have been carried out in six chimpanzees. Figure 4 shows computer generated three-dimensional cathode-ray tube displays of the distribution of radiation (blood flow) in the thorax of chimpanzee, Lillian, following injections of isotopically tagged microspheres in the right ventricular outflow tract during exposures to 1 and to 6G when in the right and the left lateral decubitus positions. The decreased blood flow to superior regions of the upper lung, concomitant with an increase in flow to the mid regions of the thorax where the hydrostatic effects of the force environment on pulmonary arterial, venous, and pleural pressures have been demonstrated to be minimal (3,4), are evident.

#### References:

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2. Sturm, R. E. and E. H. Wood:  
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Mayo Clinic Proceedings 43:803-806 (November) 1968.
3. Banchemo, N., W. J. Rutishauser, A. G. Tsakiris, and E. H. Wood:  
Effect of Gravitational Forces on Pericardial Pressure in Dogs Without  
Thoracotomy.  
Circulation Research 20:65-77 (January) 1967.
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Plans for investigative projects in the period, April 1969 - October 1969:

Work will continue on the projects described herein.

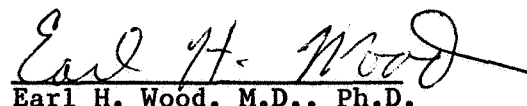
The computer programs for calculation of volume of the ventricle and generation of three-dimensional displays of the shape and volume of the ventricle are being developed further and debugged.

Arrangements are being made with Dr. Harold Sandler of NASA, Ames Research Center to surgically implant, with his active participation, a multichannel telemetry-transducer system into one of the six chimpanzees available for study in our laboratory.

It is anticipated that Dr. Sandler will deliver this telemetry-transducer system in July 1969, and assist in its implantation and subsequent use for observations of the cardiovascular reactions of the chimpanzee in the unanesthetized state and during exposure to acceleration. The relationship of the effects of plus and minus  $G_y$  (lateral) acceleration on telemetered blood flow values through the right and left pulmonary arteries to the simultaneous regional distribution of isotopically tagged microsphere emboli in the two lungs during these changes in the force environment will be of particular interest.

When miniature implantable transducers for measurement of the internal dimensions of the left ventricle are made available by Dr. Sandler, studies of the feasibility of calibrating these transducers for dynamic measurements of ventricular volume on the basis of simultaneous determinations, using biplane roentgen videometry, will be instituted.

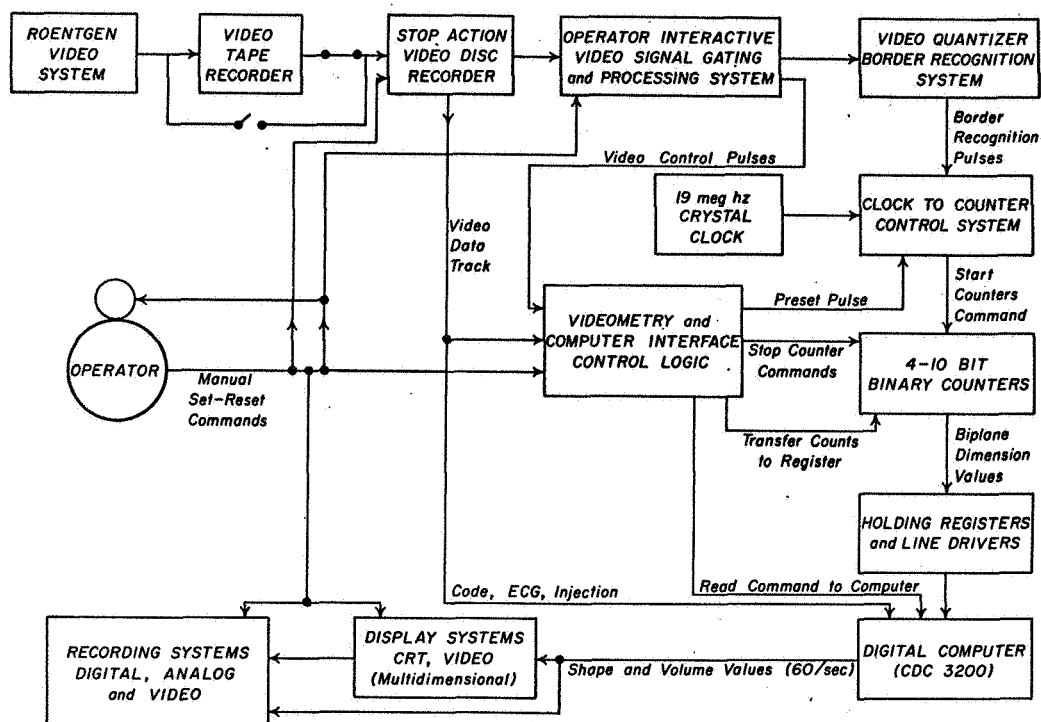
It is envisaged that these developments will lead to feasible technics for remote monitoring of changes in ventricular volume in large nonhuman primates during space flight, particularly the zero gravity state.

  
Earl H. Wood, M.D., Ph.D.  
April 1, 1969

Publications

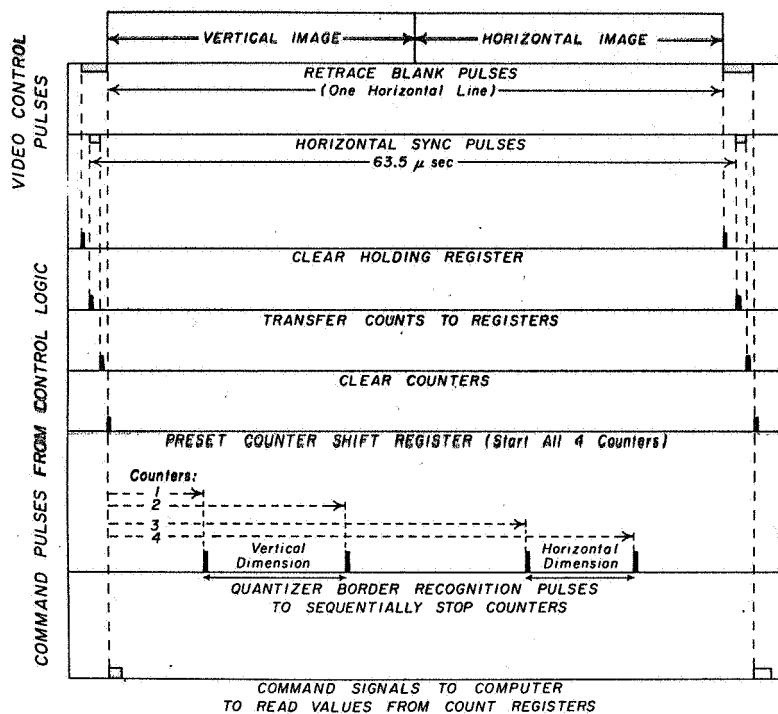
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## BIPLANE ROENTGEN VIDEOMETRY SYSTEM



**Figure 1** Block diagram of operator interactive biplane roentgen videometry-digital computer assembly for dynamic (60 per second) measurements of the shape and volume of a structure (e.g., the left ventricle), and synchronization of these data with other events (e.g., hemodynamic data). Descriptions of the biplane video systems and video quantizer cardiac border recognition systems have been published (3, 4). Measurements of the positions and the distances between the recognitions points of the cardiac borders traversed by each horizontal video line are made by using the 19 megahertz crystal clock to measure the time intervals required for the video beam to travel from the left hand border of the video field to the respective border recognitions points, as indicated in Figure 2. An example of a computer generated three-dimensional display of the left ventricular cavity, calculated from these data, is shown in Figure 3.

TIMING SEQUENCE OF VIDEO SIGNAL CONTROL PULSES AND CONTROL  
LOGIC COMMAND PULSES TO INTERFACE BIPLANE ROENTGEN  
VIDEOMETRY SYSTEM WITH DIGITAL COMPUTER



**Figure 2** Diagram of temporal sequence of electrical synchronization pulses used to control roentgen videometric measurements of the position and dimensions of biplane silhouettes of the left ventricular cavity and to input these data into a digital computer.

The diagram shows the sequence of events during one of the 63.5 microsecond periods that one horizontal video line is traversing the two images of the ventricular cavity, which are generated by the vertical and the horizontal roentgen image-intensifier systems and displayed on the right and left halves of the video screen, respectively. Since the video images of the ventricular silhouettes encompass 50-60 of the 262.5 horizontal video lines of each 60 per second video field, the data input rate to the computer during these particular portions of each video field is 63,694 values per second.

The end of the horizontal blanking pulse of the video signal (top line) starts all four counters simultaneously at the beginning of each horizontal line. Counter 1 is stopped by the recognition pulse generated when the video beam encounters the opacified left hand margin of the ventricular silhouette produced by the vertical

Figure 2 (continued)

roentgen-image intensifier assembly. Counter 2 is stopped by the recognition pulse generated when the video beam leaves the right hand margin of this silhouette. Time intervals which specify the positions and distance between the superior and dependent borders of the ventricular silhouette produced by the horizontal roentgen-image intensifier assembly are generated in an analogous fashion by counters 3 and 4. These four count values are stored in a holding register which is read by the computer at the end of each video horizontal blanking pulse. The computer is programmed to convert the count values to the biplane dimensions and positions of the margins of each of the 50-60 measured cross sections of the ventricular cavity in space, plus the shape and volume of the cavity, assuming each cross section is elliptical in shape. A computer generated three-dimensional display of these data is shown in Figure 3.

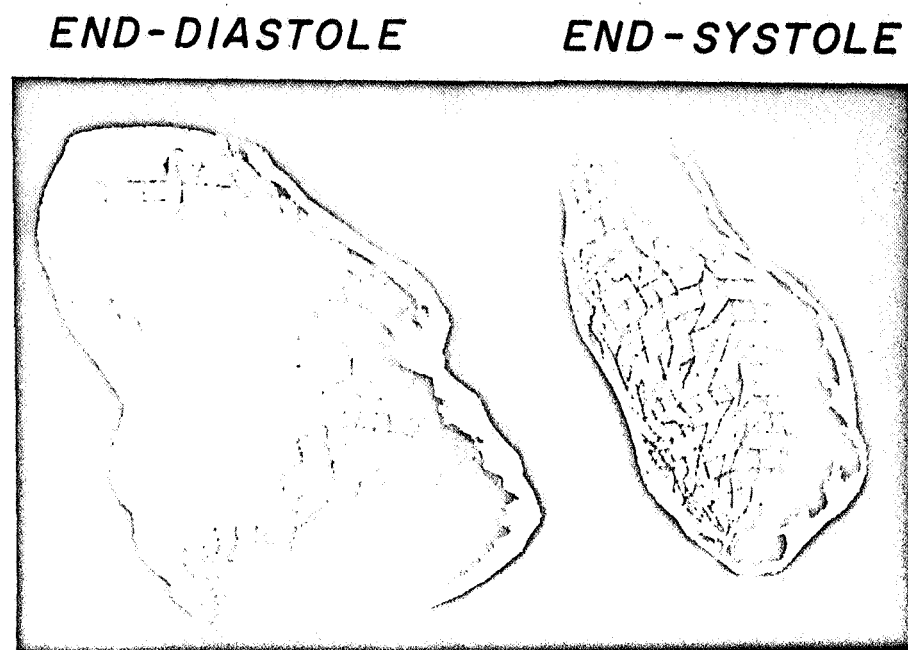
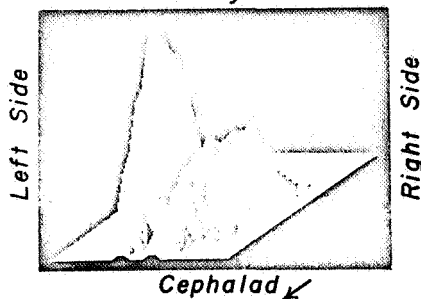


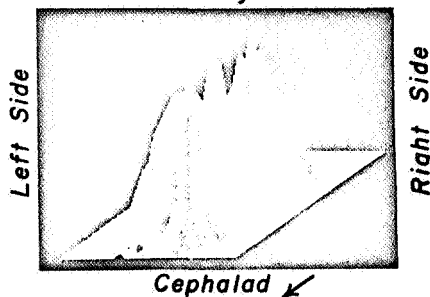
Figure 3 Picture of computer generated cathode ray tube display of three-dimensional representation of the shape of the cavity of the left ventricle at end-diastole and end-systole, based on data obtained by the roentgen videometry system illustrated in Figures 2 and 3.

LEFT DECUBITUS INJECTION  
SUPINE SCAN

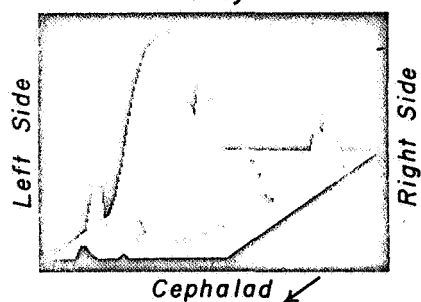
+1 Gy

RIGHT DECUBITUS INJECTION  
SUPINE SCAN

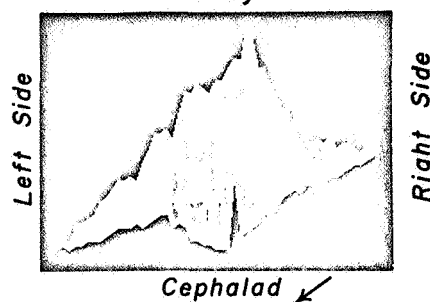
-1 Gy



+6 Gy



-6 Gy

**Figure 4**

Picture of computer-generated cathode-ray tube displays of three-dimensional representations of the distribution of radioactivity (blood flow) in the thorax of a chimpanzee during exposures to four different gravitational-inertial force environments. Injections of four differentially tagged, 35 micron diameter, microsphere emboli were made into the outflow tract of the right ventricle during exposures to +1Gy, +6Gy, -1Gy, and -6Gy. An external scintiscan of the dorsal surface of the thorax was carried out subsequent to the exposures while the chimpanzee was maintained in a constant supine body position by means of a half-body cast. The gamma radiations from each of the four isotopes used to tag each respective batch of microspheres were separated by pulse height analysis and correction for spillover between energy levels by digital computation.

Note that in the left decubitus position (left panels), when the left lung was dependent in the thorax, blood flow was greater to this lung, and that this situation was exaggerated during the exposure to 6G. Similarly, when in the right decubitus position (right panels), flow was greater to the right lung which was dependent in the thorax, and that the blood flow shifted towards the lower and middle regions of the thorax during exposure to -6Gy.

Figure 4 (continued)

Blood flow through medial regions of the lung is advantageous to the animal under this circumstance, since the changes in pleural pressure produced by acceleration are minimal in this region of the thorax. Hence, disturbances in alveolar ventilation would be expected to be minimal at this level in the thorax and, therefore, oxygenation of the blood traversing these regions of the lung, normal.

The radiation spikes outside the lung areas, seen in the lower left panel, are caused by small radiopaque radioactive markers used to correlate the anatomic dimensions of the lungs measured from a chest roentgenogram with the distribution of radiation over the thorax, determined by the scintiscanning procedure.